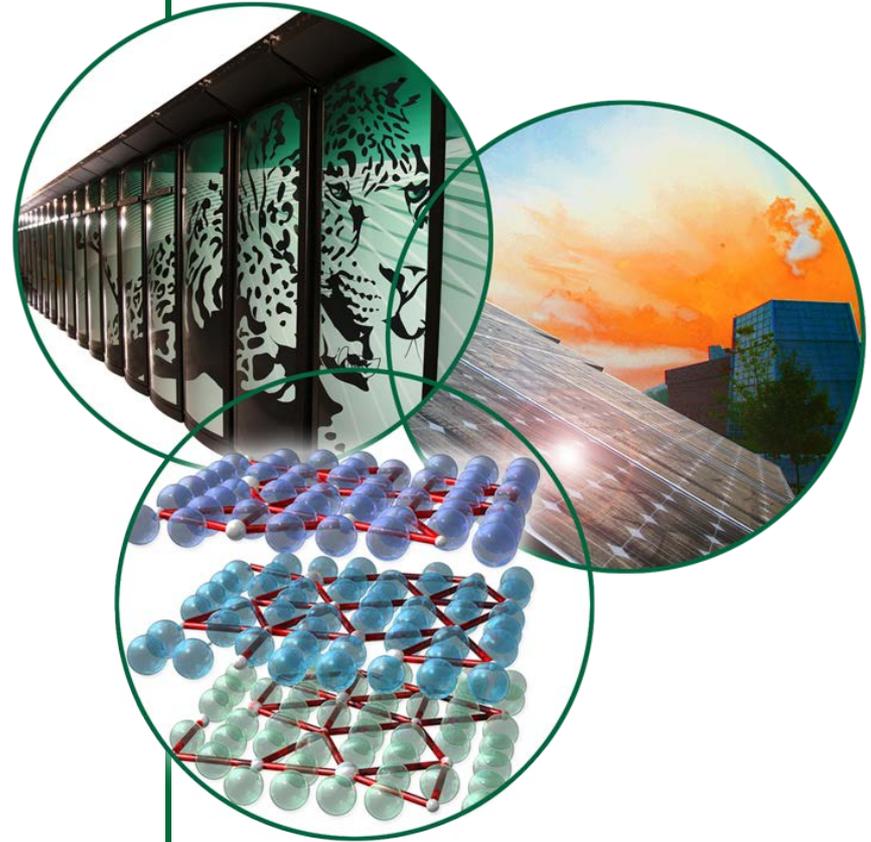


# Role of Fuel Cycle Assessment and Decision-Making in the UK

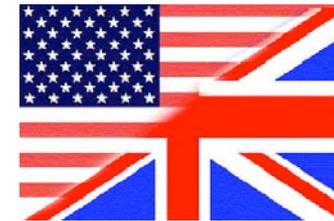
Andy Worrall, ORNL

EPRI Nuclear Fuel Cycle Assessment Workshop -

Nashville, TN, July 24-25 2012



# Historic Context



- Firstly, my “historic context”

- ~20 years in the UK nuclear industry, started with BNFL
- “Technical Authority, Reactors and Fuels” for UK National Nuclear Laboratory” (NNL)
  - » Responsible for fuels and reactors programs including fuel cycle assessment
- Joined ORNL just 1 month ago
- Therefore, thoughts offered here are my opinion, not necessarily those of my current or previous employer...

- UK Fuel Cycle Context: Diverse and complex

- Long history; 1<sup>st</sup> reactor went critical in 1950, 1<sup>st</sup> reprocessing facility operational in 1952
- Tried *many* reactors; Gas/water/metal cooled, natural U and enriched, Pu and Th.....
- Tried *many* different fuel cycles; open, closed and even modified open
- BNFL was the “glue” that bound the UK nuclear industry together
- Nuclear is firmly back on the agenda in the UK today, particularly
  - » *New build*; finance and risk is the main hurdle. Overseas investors
  - » *Legacy clean up*; progressing.....
  - » *Pu management*; decision made by UK Govt
  - » *Skills needs*; House of Lords Select Committee



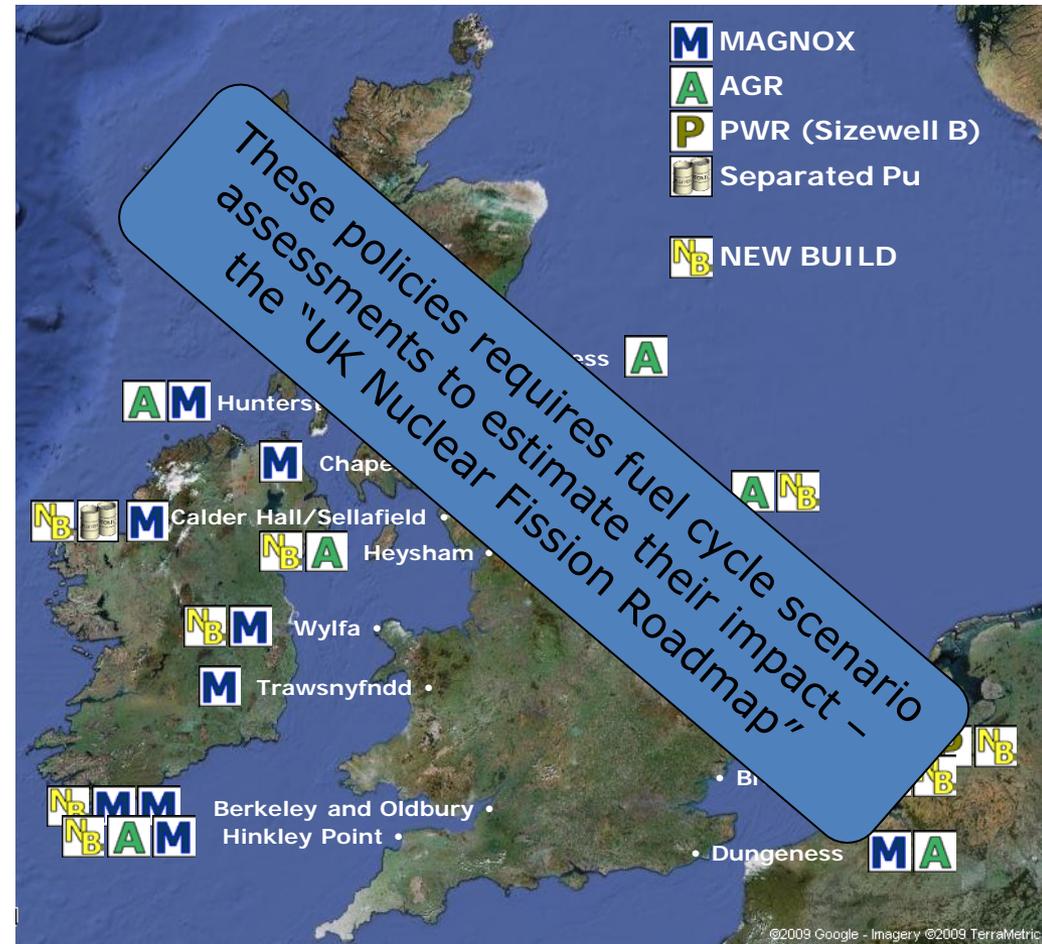
# Current day and future nuclear in the UK

## CURRENT DAY UK NUCLEAR INDUSTRY

- MAGNOX – all spent fuel reprocessed (26 units)
- AGR - some spent fuel reprocessed (14 units)
- PWR – spent fuel stored on site (1)
- 80tHM separated Pu (and rising) (Sellafield)

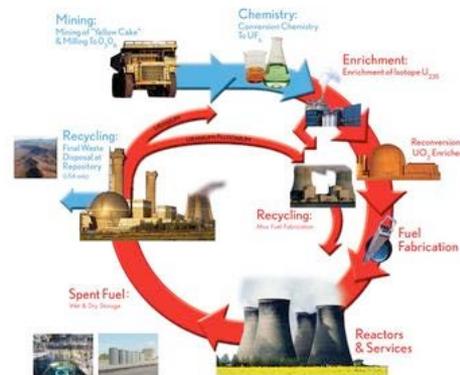
## FUTURE POSSIBILITIES

- Possible new build sites (8 proposed sites)
  - Sizewell
  - Hinkley Point
  - Oldbury
  - Wylfa
  - Cumbria (Sellafield)
  - Bradwell, Hartlepool, Heysham
- What PWR (or other?) technology?
- What fuel cycle, now and in the future?
- Pu-reuse in Sizewell B and new build fleets?
- RepU-reuse in Sizewell B and new build fleets ?
- Future reprocessing of PWR spent fuel in 2050?
- Replacement closed fast reactor fleet from 2040?



# Fuel Cycle Assessment

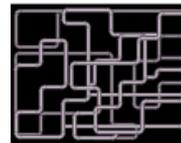
- Former Director of Operations and Research, Dame Sue Ion, recognized the importance of the independencies for BNFL's business
  - “When we ‘prod’ the fuel cycle, where does it come up and bite you?”
    - » But “bite” and “where?” and “how?” all meant different things to different BNFL Divisions/Departments and individuals
  - Decision then was to have a “holistic” view of the fuel cycle
  - Work continued in the R&D Division of BNFL and now in the NNL
    - » Tool development, application of tools and generation of underpinning data



# What is “Fuel Cycle Assessment” to the UK?

- There are several strategic aims that need to be considered when assessing any given fuel cycle:-
  - Minimize total fuel cycle cost to nuclear utilities and their customers
  - Minimize generation of waste that requires conditioning and disposal
  - Minimize overall environmental impact
  - Allow maximum recycle of fissile material
  - Satisfy political and proliferation requirements over Pu generation and its safeguarding
- Therefore, in order to assess any given fuel cycle over time (historic, current and future), require analysis of:-

1. Transformation of materials
2. Flow of materials within the fuel cycle
3. Economics



# Who are the Key Players in the UK Fuel Cycle of today (and future)?

- Utilities

- » EdF Energy (current fleet and new build)
- » Horizon Nuclear Power (E.On. and RWE) – currently up for sale
- » NuGen (GDF Suez and Iberdrola)

- Government

- » Department of Energy and Climate Change (includes Office of Nuclear Development)
- » Nuclear Decommissioning Authority
- » International Safeguards also comes under Govt (DECC)

- Regulators

- » Office of Nuclear Regulation (formerly NII) and includes OCNS (safeguards etc)
- » Environment Agency

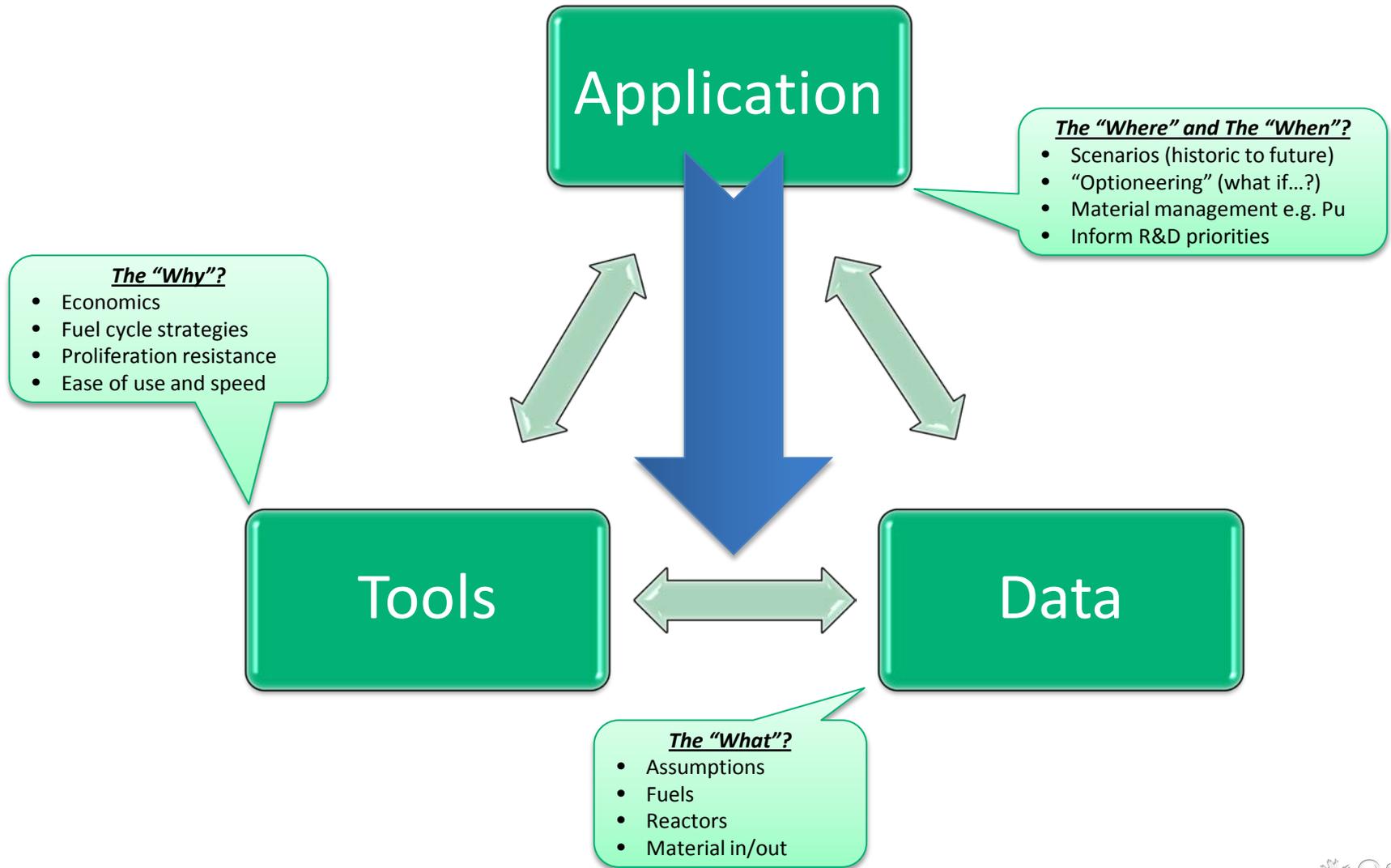
- Others

- » Vendors (now includes GE-Hitachi (PRISM) and Candu Energy Inc)
- » Thorium and MSR advocates

- And who makes the decisions?

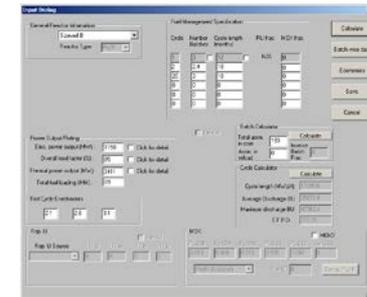
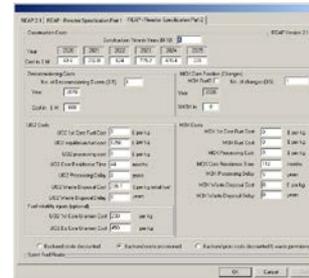
- » "The market will decide"
- » Conflicts on this include "no reprocessing of new build fuel" and closure of MOX plant

# "Building Blocks" of Fuel Cycle Assessment

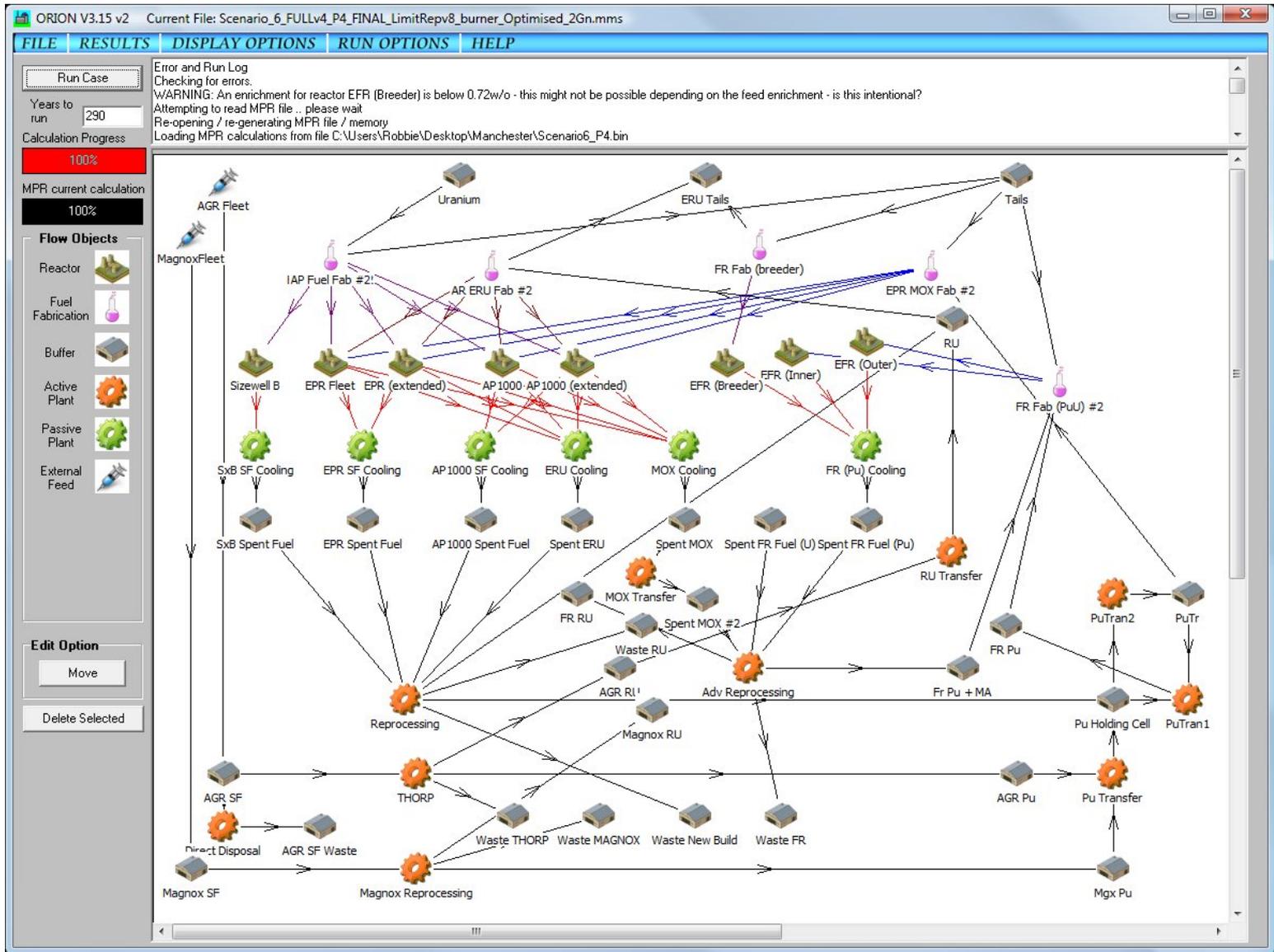


# Tools

- A number developed to reflect variety of needs
  - » ENRIC: calculates \$/kg given enrichment
  - » RUCALC: technical and economic assessment of ERU
  - » REAP: reactor (and energy generation) economics, inc Gen IV
  - » FCE: fuel cycle technical & economics analysis
  - » ORION: fuel cycle scenario modeling tool
- Often only think of the latter tool for fuel cycle “assessment”
- ORION is state-of-the-art and top of its class
  - » DANESS and ORION often quoted as the cutting edge tools

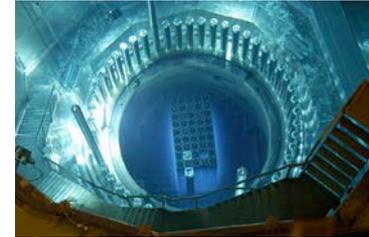


# ORION



# Data

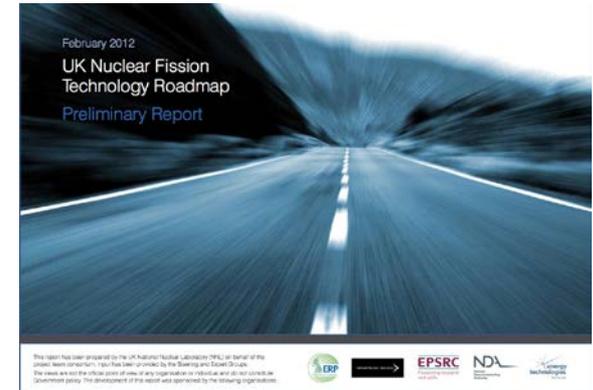
- The reactor component is clearly the most important “transformation” of materials
  - UK determined that “approximations” in reactor inventory calculations not accurate enough
    - Built in robust reactor physics models/cross sections
      - » E.g. CASMO-4, ERANOS, WIMS etc
- Need validated codes with accurate data and assumptions
- Need industrial “constraints” and real world common sense applied to
  - » E.g. size and throughput of facilities, construction times, transport of materials etc



# Application

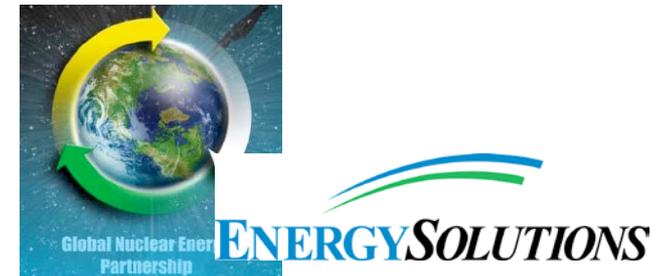
- UK future fuel cycle options

- » Nuclear Roadmap; huge step in getting “joined up” thinking in the UK. Nobody taking ownership of the issue, nobody truly evaluating the options – who is the “customer” in a “leave it to the market” policy?
- » Pu management
- » Sustainability
- » Metrics is a very difficult subject !



- US future fuel cycle options

- » GNEP
- » NWTRB

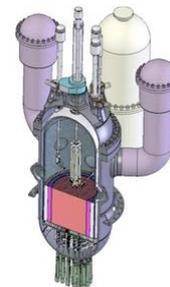


- European Framework Programmes

- » GoFASTR
- » PUMA

- Others

- » Support to UK energy review
- » Value of RepU





# Conclusion

- The role of fuel cycle assessment is to “aid in the decision making process”
  - Investors, utilities, governments.....
  - DECC has now recognized the benefit of this type of analyses and work is now underway to assess the needs and how to get there
    - » Work includes determining metrics, completing fuel cycle assessment and technology choices
- What output, messages and decisions have been relevant?
  - Cost comparisons e.g., ERU vs NIU, MOX vs UOX, FRs vs thermal, closed vs open fuel cycle
  - Logistical comparisons e.g., Do we have enough Pu from the historic/new fleet to feed a FR fleet?
  - Size of plants needed e.g., Do we need a THORP-2, or x2 THORP-2?
  - Resource utilization e.g., U ore, ERU, Pu stockpile depletion, spent fuel utilization
  - Waste arisings e.g., VHLW generated, total radiotoxicity
  - Timing e.g., When do we need the plants on line?
  - R&D choices e.g, what systems can achieve our objectives and what demand does that place on the fuel, reactor, fuel cycle?
- Final thought...
  - Fuel cycle *MODELING* is only one part of fuel cycle *ASSESSMENT*
    - » *The two are often interchanged incorrectly*